



Achieving low to zero GWP HVAC&R

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U.S. DEPARTMENT OF
ENERGY

Office of ENERGY EFFICIENCY
& RENEWABLE ENERGY

BUILDING TECHNOLOGIES OFFICE

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Key BTO Initiatives

Advanced Building Construction (ABC) Initiative



- ✓ New building materials
- ✓ 3D printing
- ✓ Modular construction
- ✓ Digitization
- ✓ Robotics
- ✓ Workforce development



Energy, Emissions and Equity (E3) Initiative



- Cold Climate Heat Pumps
- HPWH for decarbonization
- Low GWP refrigerants
- Better Buildings Low Carbon Pilots

These initiatives focus on advancing decarbonization technologies and strategies with a focus on affordable housing and disadvantaged communities

Why Grid-interactive Efficient Buildings?



Integrate the growing share of variable renewable energy



Reduce costs to replacing aging electricity system infrastructure and improve system reliability



Assist in achieving decarbonization goals through reduced fossil fuel generation and increased heating electrification



Optimize energy use based on customer preferences

FLEXIBLE BUILDING LOADS CAN BENEFIT OWNERS, OCCUPANTS, AND THE ELECTRIC GRID

Achieving Zero Carbon HVAC&R systems

A future low carbon grid

Heat pumps to lower building GWP footprint

Lowering Customer Energy Costs

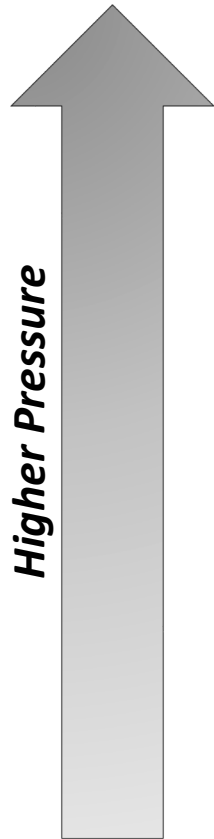
Continued focus on energy efficiency



Reducing direct emissions from building

Low GWP refrigerants

What we need are heat pump and refrigeration systems that use ultra-low GWP systems while increasing system efficiency and maintain safety

Current Refrigerants and the leading Replacements

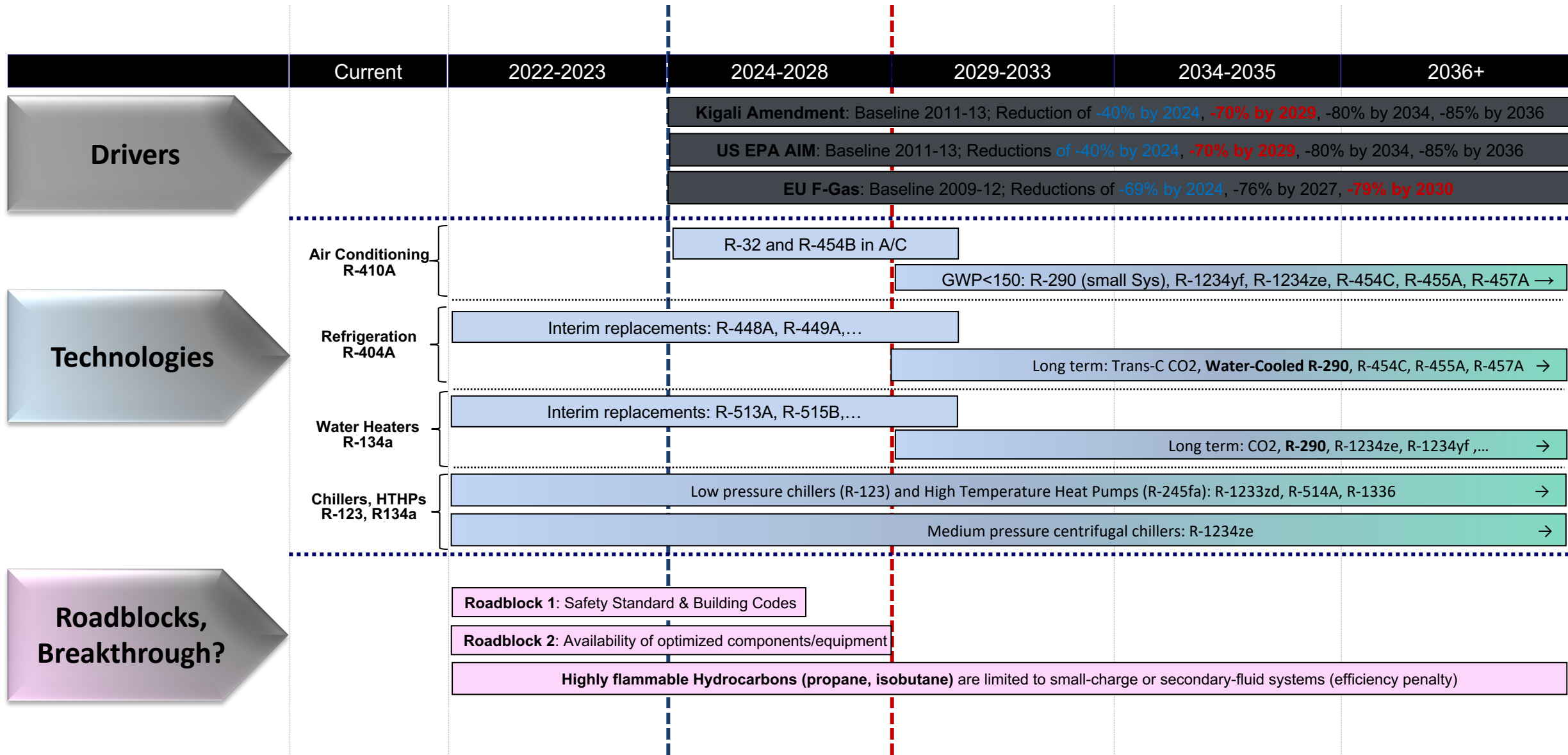


Current Refrigerant	Class 1	Class 2L	Class 3
<p>R-410A GWP=2,088 Residential & Commercial AC Reversible Heat Pumps Scroll Chillers</p> 	R-466A GWP=733 (new Sys)	R-32 GWP=675 R-454B GWP=466	R-290 GWP=3 (Small charge)
<p>R-404A GWP=3,922 Commercial refrigeration</p> 	R-448A GWP=1273 (retrofit) R-449A GWP=1397 (retrofit) R-744 GWP=1 (Transcritical)	R-454C GWP=148 R-455A GWP=148 R-457A	R-290 GWP=31 (water-cooled, Self-contained)
<p>R-134a GWP=1,430 Domestic & Commercial Refrigeration Heat Pump Water Heaters Centrifugal chillers</p> 	R-513A GWP=631 R-515B GWP=293	R-1234yf GWP = 4 R-1234ze GWP = 7	R-600 GWP=1 (refrigerators) R-290 GWP=3 (HP water heaters)
<p>R-114 GWP=10,000 and R-245fa GWP = 1030 Centrifugal chillers High Temperature Heat Pumps Organic Rankine Cycle</p> 	R-1233zd GWP=1 R-1336 GWP= 1 R-514A GWP=2		

GWP values are based on IPCC AR4 (used by most regulations)

Natural refrigerants shown in bold-green fonts

Timelines for various refrigerant transitions related to regulations



Air Conditioning: Residential and Commercial



Application	ASHRAE Name	ASHRAE Class	GWP (AR4)	Composition (%)	Replaces	Cap	Eff	Comments
Residential AC Commercial AC (Rooftops, VRF)	R-32	A2L	675	R32 (100%)	R410A	110%	105%	~30-35°F higher discharge temperature than R410A.
	R-466A	A1	733	R32/R125/CF3I (49%/11.5%/39.5%)	R410A	99%	101%	~15°F lower discharge temperature than R32. Thermal stability under evaluation. Not a long term replacement
	R-454B	A2L	466	R32/R1234yf (68.9%/31.1%)	R410A	97%	101%	~15°F lower discharge temperature than R32. Not a long term replacement
	R-454C	A2L	148	R32/R1234yf (21.5%/78.5%)	R22, R407C, R410A	62%	95%	Potential long term replacement due to GWP<150. It will require significant redesign of the system

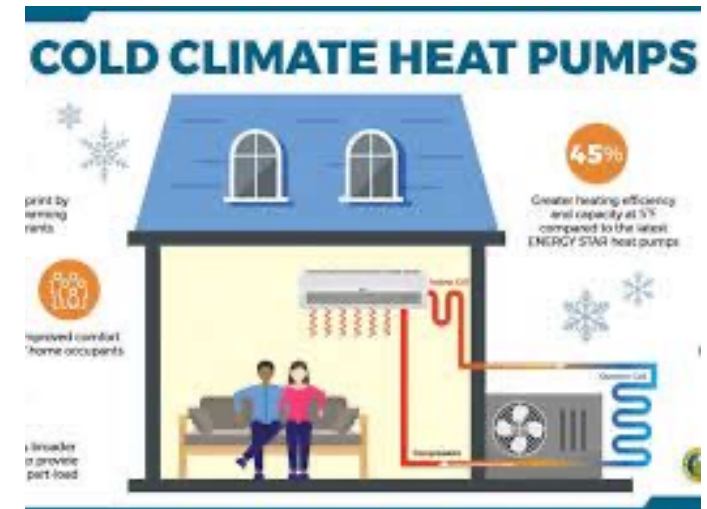
**Replacements with GWP<750) are considered short term - Options with GWP<150 could be long term
Propane is limited to low-charge equipment with charge below 150g (example: window A/C)**

New innovations like the Fraunhofer LC150 initiative propane system which achieved ~ 30g/Ton of heating capacity are exciting developments ([Propane-based Refrigeration Circuit for Heat Pumps Achieves New Efficiency Record - Fraunhofer ISE](#))

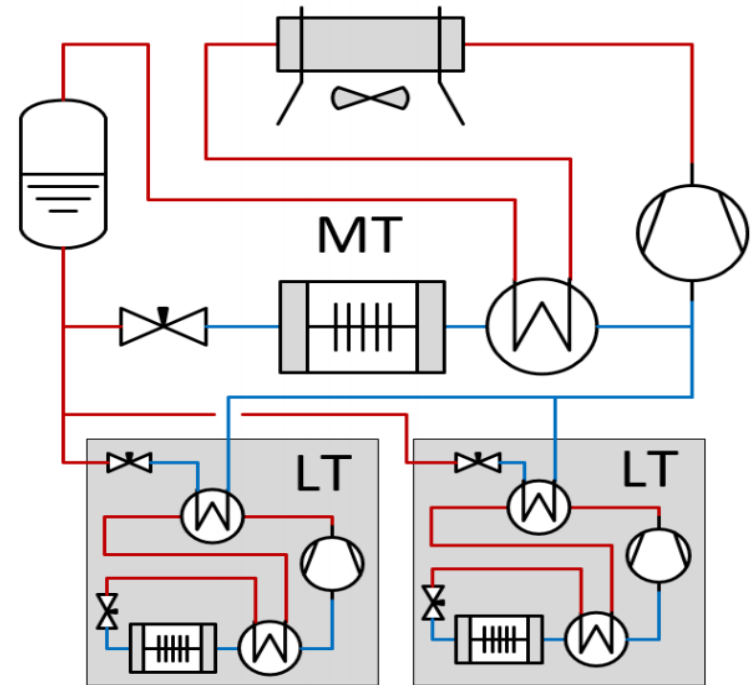
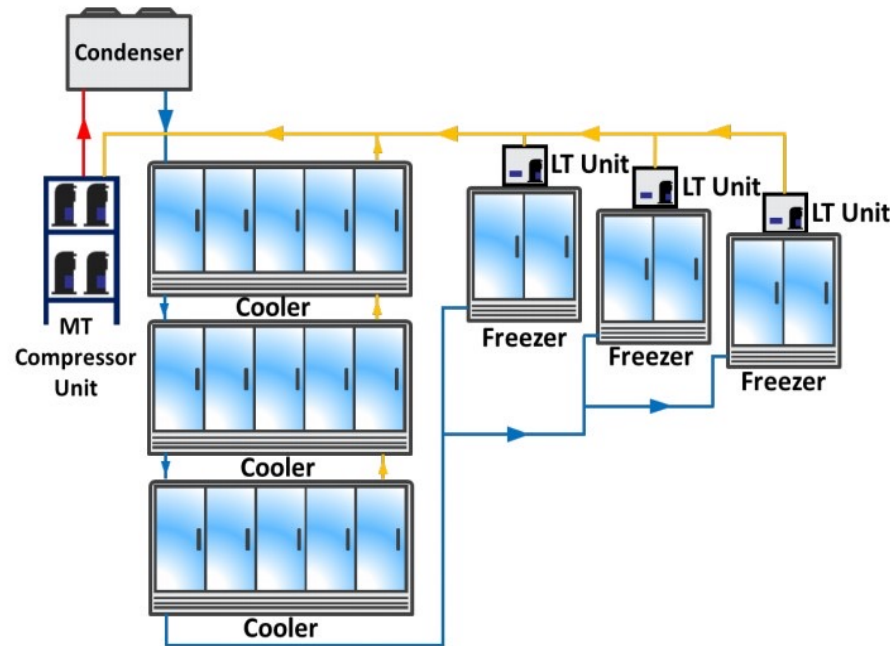
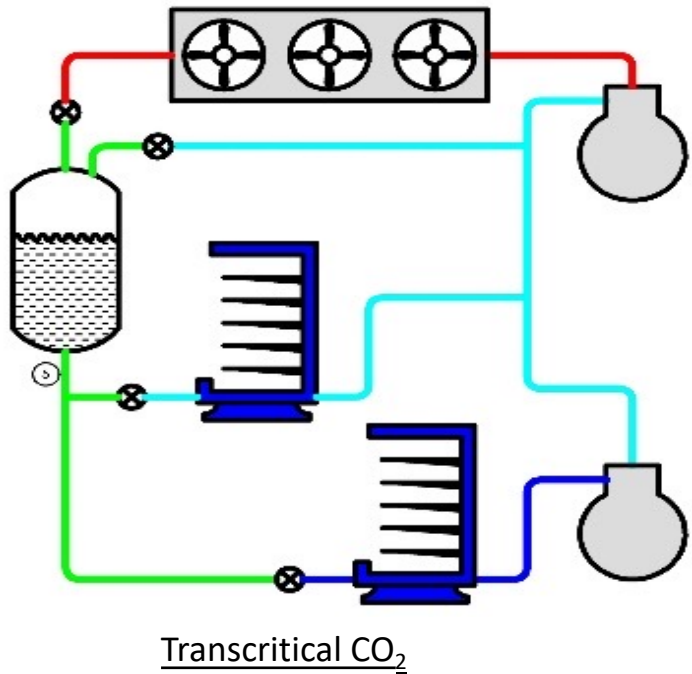
Heat Pumps and Future HVAC

- The Cold Climate HP Challenge: Work with the industry to evaluate enhanced Heat Pump technologies to deal with Cold Climate conditions.
- Enabling residential heat pump development with ultra low GWP refrigerants (GWP<150).
- Development of next generation heat exchangers (compact, efficient, low charge) to enable the use of environmentally friendly Low GWP refrigerants leading to approximately 96% reduction in direct emissions.
- Enable the development of High efficiency compressors for low GWP refrigerants (target: 4% higher efficiency than current R-410A compressors). Reduce direct CO2 emissions by at approximately 96%.
- High-efficiency/Low-cost Rooftop can enable the DOE to fulfill its plan to reduce CO2 emission by 30% in Northern climates [1H]. High-efficiency/Low-cost Rooftop can enable the DOE to fulfill its plan to reduce CO2 emission by 30% in Northern climates.

High Efficiency HJP and HVAC Systems are feasible – Need to reduce cost to enable them



Commercial Refrigeration applications



- Evaluation of Transcritical CO₂ booster system for commercial refrigeration.
- Micro-Booster refrigeration system using ultra low GWP R-1234yf. High TRL technology enabled by collaborating to validate performance at the lab level and in trials.
- Micro-cascade using non-flammable and low GWP refrigerants. Another high TRL technology that can be enabled by DOE's lab and field evaluations.

Thank you

Ram Narayanamurthy

Ram.Narayanamurthy@ee.doe.gov